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HUMAN FACTORS EXPERIMENTS WITH TELEVISION

by

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ABSTRACT. Three experiments on target detection and identification with television (TV) were conducted in a laboratory setting. Experiment 1 found that small, square targets with a contrast of 18% against a darker background needed to subtend about four TV raster scan lines on the TV monitor to be detected. Extrapolation of the data indicates that targets with 7% contrast against a lighter background require about six TV lines across them to ensure detection.

Experiment 2 compared observer performance on several TV monitor viewing tasks in a daylight environment to performance in a darkened environment. Performance on the shades-of-gray test and the resolution test was worse under daylight conditions. One less shade-of-gray (by the RETMA standard) was discernible in daylight than in darkness. The critical detail in the resolution patterns had to be 1.3 times larger in daylight than in darkness to obtain the same performance level. There was no significant difference between symbol legibilities under the two conditions.

Experiment 3 was conducted with an 875-line TV system. Measures of resolution and symbol legibility compared favorably with previous 525-line data when results were expressed either as a function of angular subtense of a target to the observer or the number of scan lines on the monitor crossing the target. The results are compared to other studies of symbol legibility.

It is concluded that the 525-line data can be used to predict performance on other TV systems if performance is expressed as a function of the number of raster scan lines making up the image and the angular subtense of the image to the observer's eye.

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FOREWORD

These experiments on target detection and identification with television were conducted at the Naval Weapons Center, China Lake, California, between January and August 1967. The work was supported under Task Assignments AAW-203-RDT&E-10-7-W1721 (Point Defense) and AIR 510-103/216-1W107-B0-01 (Condor).

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EXPERIMENT 1
DETECTION OF POINT TARGETS ON TV

INTRODUCTION

This experiment was conducted in the laboratory to furnish preliminary data on the detection of small, square targets presented on a TV monitor. The data are preliminary in that (1) only target size was varied systematically, and (2) data applicability is restricted to TV displays operated at the same brightness and contrast levels used in this experiment.

APPARATUS

The stimulus material consisted of 18- by 28-inch charts of flat gray paper on which small, square targets were glued. The charts were placed (one at a time) on a stand and illuminated by a 1,000-watt incandescent bulb placed 7 feet in front of them. A TV camera was placed behind the light source so that it "looked" beneath it at the chart in the stand. The camera was connected directly to the TV monitor being viewed by the observer. The experimental setup is shown in Fig. 1.

The charts were made from an artist's paper designated as Trutone background paper CVG4. This is a gray shade approximately equivalent to the Munsell notation N8 that has a 59.1% reflectance. Each chart was divided into six squares. Each square was either blank or contained one, two, or three targets, randomly arranged (Fig. 2). The targets were made from either CVG3 or CVG5 paper, and they were either 2, 3, 4, or 5 millimeters on a side. If more than one target appeared in one square, all were the same size and contrast.

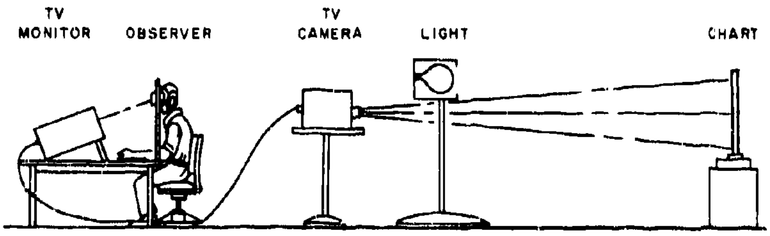

FIG. 1. Experimental Setup for Detection of Small, Square Targets on TV.

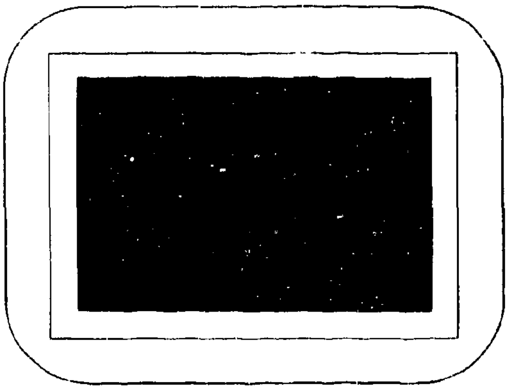

FIG. 2. Typical Display Chart as Seen on TV Monitor.

Target/background contrasts[1] were calculated from brightness measurements made on large sample patches of the papers used. Since a Spectra spot photometer with the eye-response filter was used to make the measurements, contrasts are in photometric terms and not directly applicable to TV pickup-tube response analysis. The photometric contrast of the gray G5 targets against the gray G4 background was -7% when illuminated by the 1,000-watt (110-volt, 60-cycle) incandescent bulb. The gray G3 targets had a contrast of 18% against the same G4 background.

There were two target/background contrasts, four target sizes, three target group sizes (one, two, or three targets in a square), and two replications, for a total of 48 presentations. The inclusion of 18 blank squares resulted in a total of 66 squares on 11 charts. Order of presentation was randomized for group size (zero, one, two, or three targets), target size, and contrast.

The camera was a Cohu Model 3100 (525-line, 10-megahertz bandwidth) with a Schneider-Kreuznach f1:2/50-mm lens. It was serviced and adjusted for optimum performance by a factory repairman just before the tests began. The 8-inch monitor was a Model CNB8 Conrac driven directly by the camera. The video-frequency response of the monitor is given as flat (±1 db) to 10 megahertz. The initial brightness/contrast adjustments of the monitor were made while viewing a standard RETMA test chart. When a "good picture" was obtained on the monitor, the gray-scale rendition was measured. Brightness measurements were made on the chart (Fig. 3), then on the monitor, with a Spectra Model UB $\frac{1}{4}$° Brightness Spot Meter. The calibration chart was used to adjust the gray-scale rendition of the camera-monitor system before and after each observer was tested. Individual

[1]Contrast is defined in Appendix A.

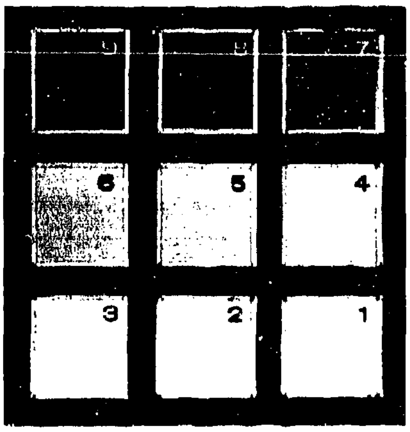

FIG. 3. Photo of a Gray-Scale Rendition Calibration Chart.

brightness values are given in Appendix A, and mean values are shown in Fig. 4. The stimulus material used only a small part of this total gray-scale range as shown in Fig. 4.

Before the tests were started, the safety glass was removed, and the tube face and both sides of the glass were cleaned with lens cleaner.

To reduce unwanted light, the monitor was placed on a table painted flat black in a room that was also flat black. Glassless spacing goggles mounted on the table allowed the viewing distance to be kept constant (25 inches from tube face to eyeball). An audio tape recorder used for playing recorded instructions to the observers was placed on the table. The observers wore sound earprotectors similar to those worn by jet aircraft ground crewmen to reduce unwanted noise during the test.

VIEWING GEOMETRY

Throughout this report, the terms TV raster scan line, active TV raster scan line, or TV scan line are used. These terms all refer to a single, continuous, narrow strip of the picture area containing highlights, shadows, and halftones. It is formed by one horizontal sweep of the scanning spot in a cathode-ray tube.

The dimensions of the targets referred to in this report are given in terms of angular subtense and number of scan lines making up the target. If a target is 10 TV scan lines high, it is composed of 10 scan lines and 9 blank spaces (there is one blank space between each two adjacent active scan lines). The target would then be made up of 19 lines, only 10 of which carry information.

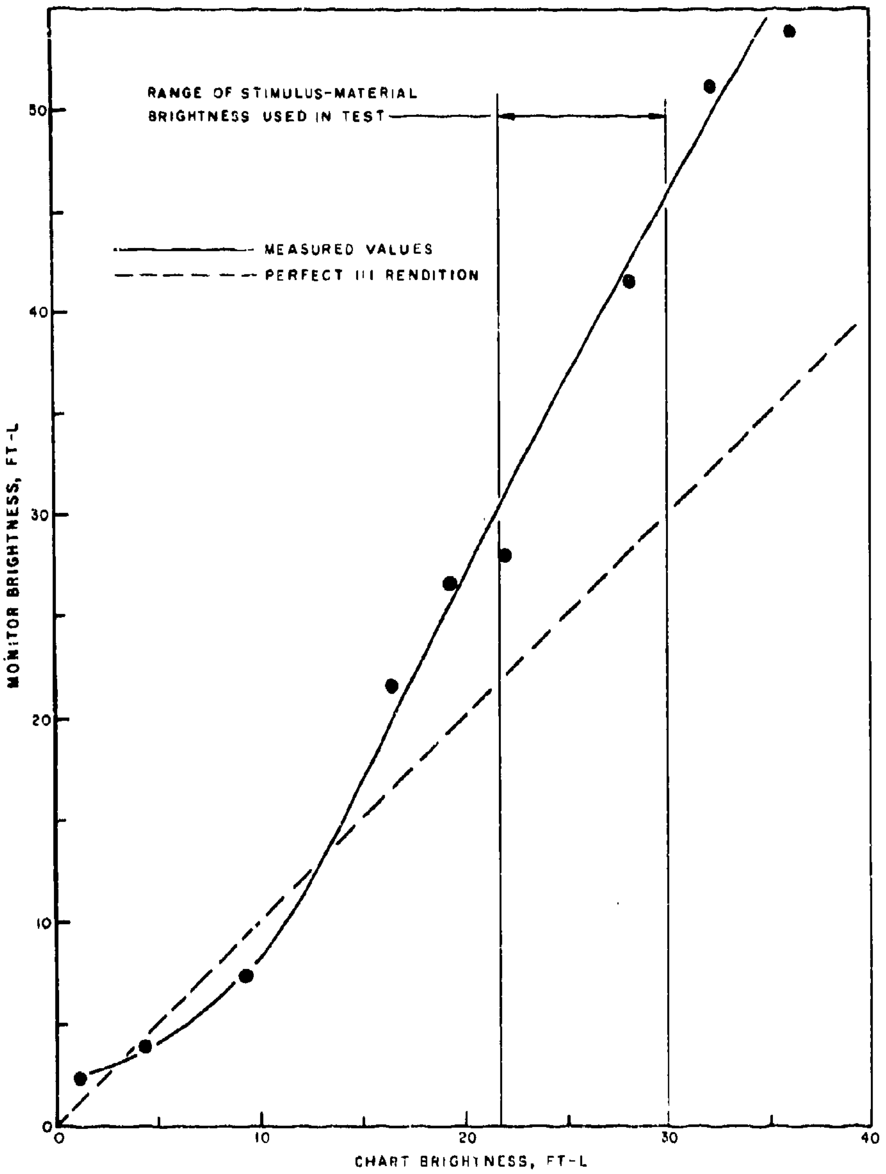

FIG. 4. Contrast Rendition of TV System Used in Point-Detection Experiment.

The viewing geometry in the first test was such that one TV scan line and the blank space beside it subtended 1.75 minutes of arc to the observer's eye. An object 1 inch high on the chart was 0.20 inch high on the TV monitor and subtended about 16 active TV scan lines. Although each line was distinct from its neighbor, inspection of the raster with a seven-power eye loupe revealed that there was some line pairing.

In the second test (see next section), one TV scan line and the blank space again subtended 1.75 minutes of arc to the observer. However, a 1-inch object on the chart was 0.24 inch on the monitor and subtended 19 TV scan lines. The size of the targets used in the tests is given in Table 1.

TABLE 1. Target Size

Target size on chart, mm	Width of square target on monitor					
	Inches		TV scan lines		Min. of arc	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
2	0.016	0.019	1.2	1.5	2.1	2.6
3	0.024	0.028	1.8	2.2	3.2	3.8
4	0.032	0.038	2.5	3.0	4.5	5.2
5	0.040	0.047	3.1	3.7	5.5	6.4

OBSERVERS AND PROCEDURE

The 10 observers for this experiment were males between 23 and 38 years old. There were three engineers, five technicians, and two Navy pilots. Visual acuity was measured on the Armed Forces Vision Tester a few days before the tests. All had uncorrected near binocular visual acuity of 20/15 or better. Five observers were used in each of the two parts of the experiment.

The TV equipment was allowed to warm up for about 1 hour before the tests began. Brightness measurements were made on the calibration chart just before the observer was brought into the test room. The observer was seated, and the recorder with the taped instructions (see Appendix A) was started. The purpose of the experiment was explained, the spacing goggles and chair were adjusted, and a sample chart was shown. The observer was to state the number of targets he saw (none, one, two, or three) in each square on the test chart, starting in the upper left and going across to the right. He was required to give one of the four answers for each square. After three practice charts were presented, the 11 actual test charts were shown. There was no time limitation, and the observers worked at their own speed. After the test, brightness measurements were again made on the calibration chart.

After the first five observers were tested, inspection of the data indicated that the low-contrast targets were very difficult to detect, even the largest ones. It was decided to run a second test with five more observers, moving the camera as close to the charts as possible and yet keeping the whole chart picture on the monitor. This procedure effectively increased the size of the targets on the monitor by a factor of 1.2. This new data provided a verification and extension of the data from the first five observers (Test 1).

RESULTS

False alarms (targets reported when none were present) are shown in Table 2 for each observer. It was desired that the false-alarm rate be about the same for all observers, and low for this experiment. Note that in Test 1 observer No. 3 had a high false-alarm rate. The most common error was to report one target when none was present.

TABLE 2. False Alarms

Observer	Zero targets reported correctly	Zero targets reported as		
		1	2	3
1	14	2	1	1
2	18	0	0	0
3	8	10	0	0
4	14	4	0	0
5	16	2	0	0
6	16	2	0	0
7	12	5	1	0
8	18	0	0	0
9	17	1	0	0
10	11	4	1	2

The performance scores are shown in Fig. 5 and 6 and summarized in Fig. 7. The higher contrast targets are easier to see, and as size increases, the performance is better.

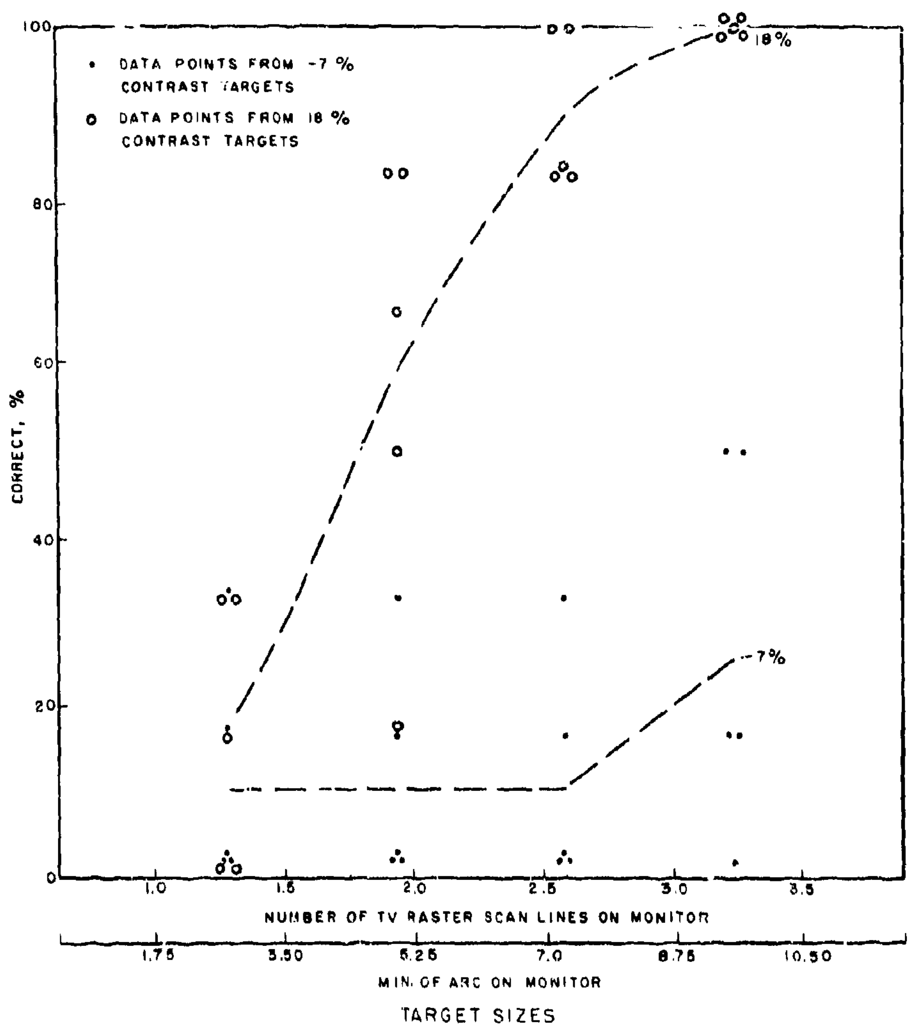

FIG. 5. Observer Performance in Correctly Counting Number of Targets Present: Test 1.

The data indicate that light targets against a darker background with a contrast of 18% must subtend three to four TV scan lines (and 7 minutes of arc to the observer) before they can be consistently counted correctly. Extrapolation of the data indicate that for targets darker than their background and with a contrast of 7%, six TV scan lines (and 10.5 minutes of arc) are required for reliable counting. The last figure should be verified by further experimentation, however. The extrapolation was based on the assumption that the shape of the curve would be the same as that for the 18% contrast targets.

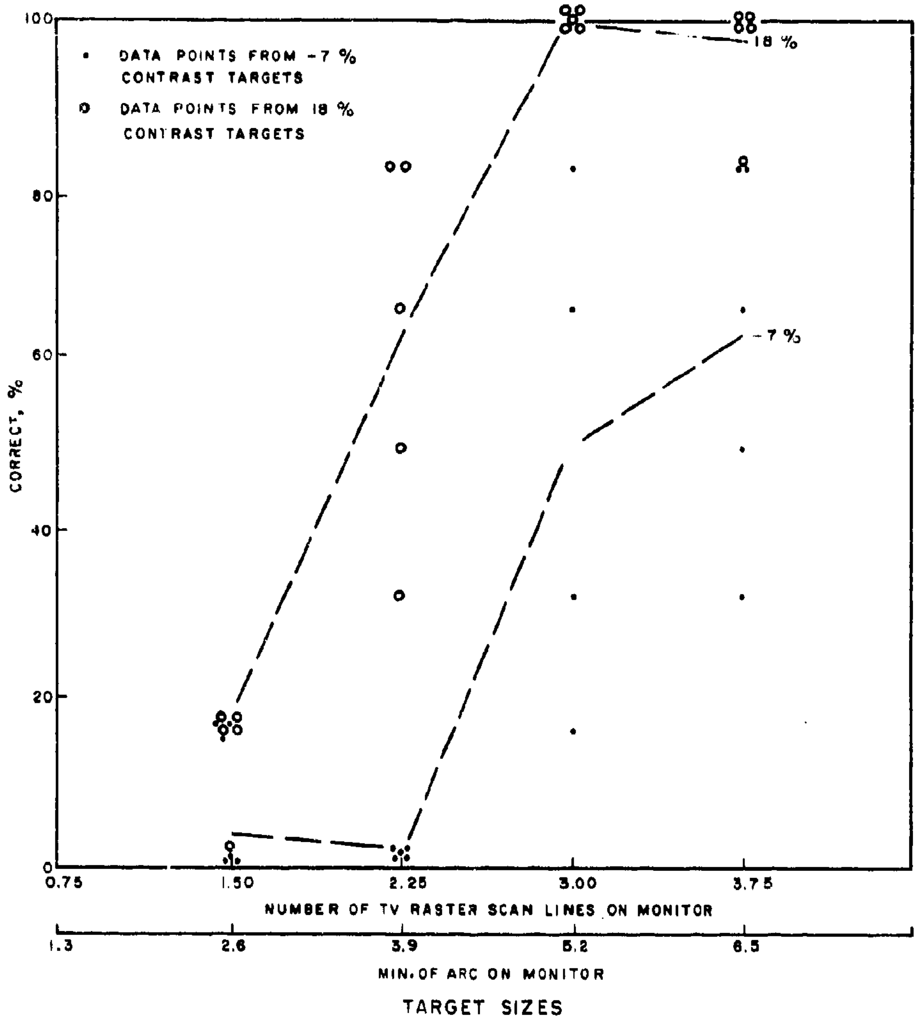

FIG. 6. Observer Performance in Correctly Counting Number of Targets Present; Test 2.

LIMITATIONS OF THE RESULTS

The following must be kept in mind when applying the results of this preliminary experiment:

1. The observers had good, uncorrected, near visual acuity.

2. The observers were not trained for the task, nor did they have feedback on their performance during the tests.

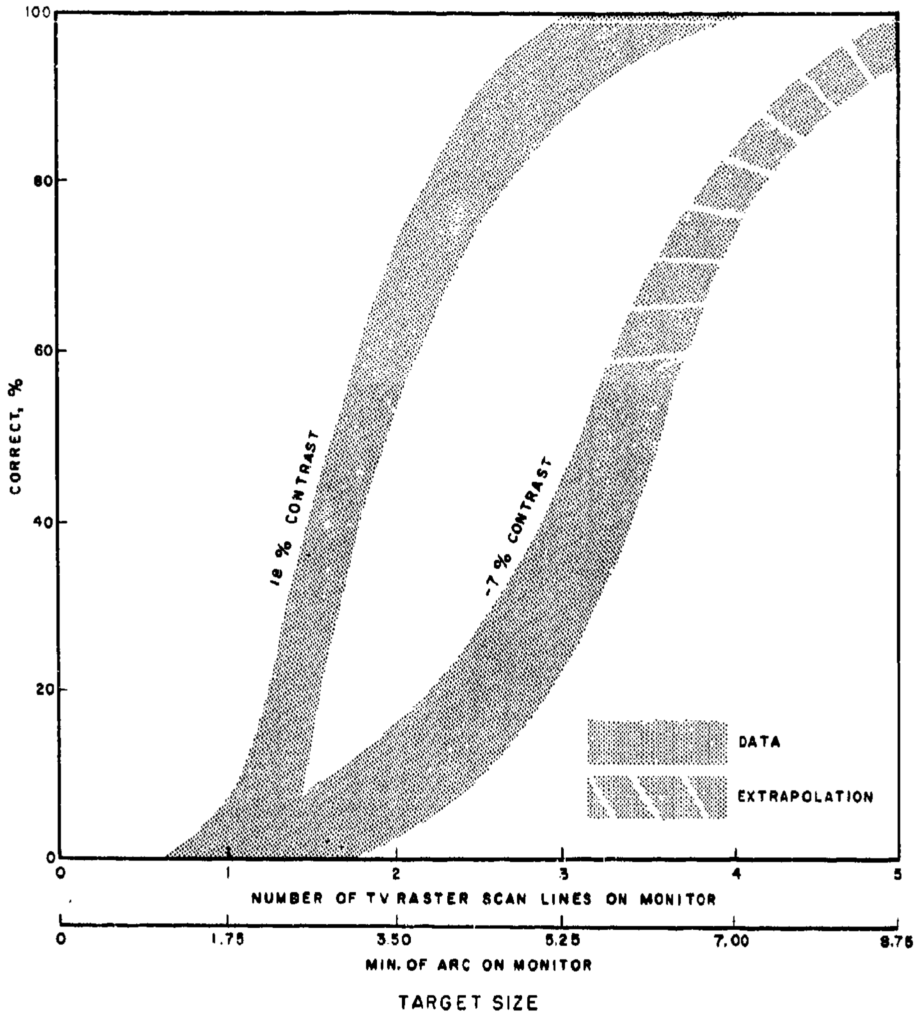

FIG. 7. Summary of Observer Performance in Correctly Counting Number of Targets Present.

3. This task was a detection experiment in which the criterion for success was the ability to correctly count the number of objects in each display frame. Forced choice was used for each frame, that is, the subjects had to give an answer.

4. The observers were volunteers, and they performed in a laboratory environment without operational motivations (such as, "we're being attacked").

5. The TV camera was adjusted by a factory maintainance man before the tests, and the system was kept clean and properly adjusted throughout the tests.

6. The TV system was a 525-line, 10-megahertz system with the same, somewhat arbitrary, brightness and contrast adjustments maintained throughout the tests. The observers were not allowed to change settings.

7. The use of only two target-contrast magnitudes and signs (18% light on darker background, 7% dark on lighter background) has confounded the two effects. It is generally assumed that contrasts of equal magnitude are equally visible, regardless of sign, so the difference is probably due to the difference in magnitudes.

EXPERIMENT 2

LIGHTING EFFECTS UPON COCKPIT TV VIEWING

INTRODUCTION

Experiments on target acquisition with TV have accompanied the introduction of TV in military systems. Most of these experiments have been conducted in the laboratory under more ideal viewing conditions than found in the anticipated operational situation. In airborne systems employing a TV monitor mounted on the panel in the cockpit, sunlight can front-illuminate the TV tube face, reducing the usefulness of the picture to the observer. Although hoods that mask the tube face or filters that reduce the ambient light effects can be used, it is not always possible or desirable to use them.

This experiment was conducted to obtain a preliminary estimate of the effects of ambient illumination upon TV viewing in a cockpit. Two conditions were selected for testing: (1) TV-monitor viewing in a completely dark environment, and (2) monitor viewing with the aircraft in direct sunlight but with the TV tube face in the shade. An 8-inch commercial TV monitor was installed in an aircraft cockpit located atop a tower in the open sunlight. Observers first viewed resolution, gray-scale rendition, and geometric symbol-legibility test charts under conditions of ambient lighting, and then with the cockpit darkened by a tarp

cover. The data presented herein allow a comparison of the two viewing modes and can be used as preliminary estimates of the upper and lower bounds of lighting effects on TV picture usefulness.

APPARATUS AND OBSERVERS

An A-4 aircraft cockpit mounted atop a tower in the Mojave Desert in California was used as the test laboratory. The cockpit was about 60 feet above the desert floor, and data were collected on clear days with the cockpit always in the open sunlight. For the uncovered cockpit test runs, testing time was held between 0830 and 0930; the sun's elevation varied between 45 and 55 degrees above the horizontal. The cockpit faced north so that the TV monitor was always in the shade of the glareshield. In addition, the observer in the cockpit was required to wear a black shirt-cover to hold internal reflectance constant. Cockpit ambient brightness was indicated by a white Munsell paper with a 90% reflectance that was taped to the panel adjacent to the TV monitor. Its brightness in the sunlit condition was about 130 footlamberts. Readings made through a hole in the tarp when the cockpit was covered showed that the same white paper had a brightness of about 35 footlamberts. The brightness of four different light-gray levels displayed on the TV monitor was 145, 215, 280, and 295 footlamberts. When the tarp was removed, these brightnesses went up to 260, 320, 360, and 370 footlamberts, respectively.

An 8-inch, 525-line Conrac TV monitor was mounted on the cockpit panel and driven via a video amplifier by a Cohu Model 3100, 525-line, 10-megahertz TV camera located in a test room. The camera was operated with fixed sensitivity, that is, fixed vidicon target voltage. Tape-recorded instructions were transmitted over an intercom system to head sets worn by the observer and the experimenter on the tower. The observer's responses were picked up by a lip-mike. The experimenter on the tower heard the responses over a head set, and a second experimenter in the test room heard them over a speaker.

The viewing distance of 24 inches between the observer's eyes and the TV monitor face was controlled by glassless spacing goggles fixed to the cockpit. The observer was asked to make all observations with his face against the goggles.

Illuminated charts containing the test patterns were located about 14 feet in front of the camera. One practice and three actual test charts were used in both the resolution and gray-scale rendition tests. The symbol-legibility test comprised three charts, with no practice chart. The symbols were black on a white background, with an estimated contrast of -80%. Sketches of the chart formats are shown in Fig. 8, 9, and 10.

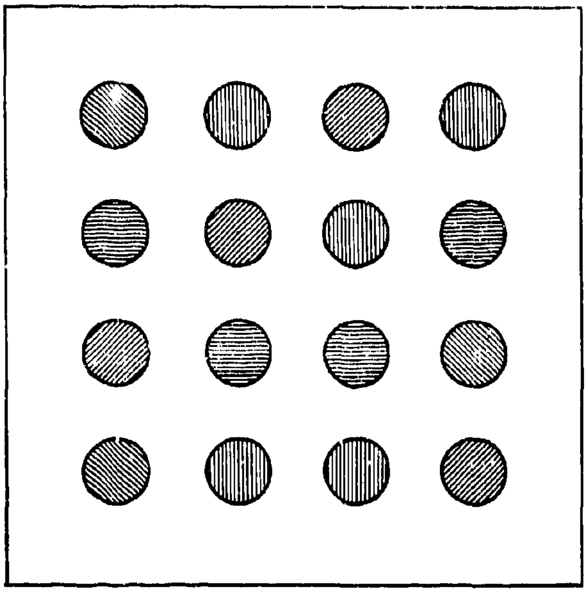

FIG. 8. Sketch of Linear-Grid Resolution Test Chart.

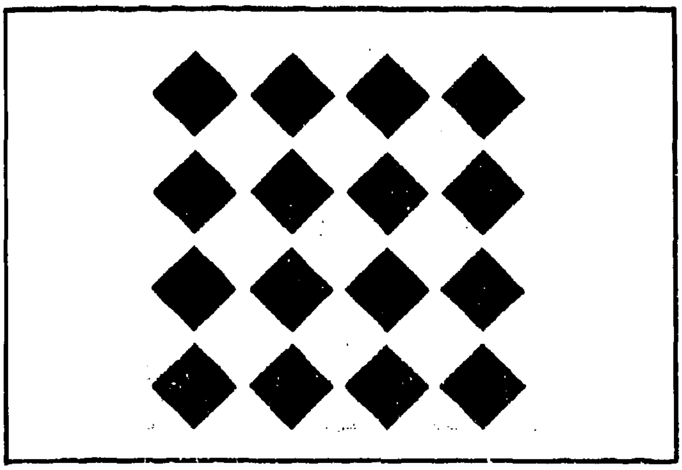

FIG. 9. Sketch of Gray-Scale Chart.

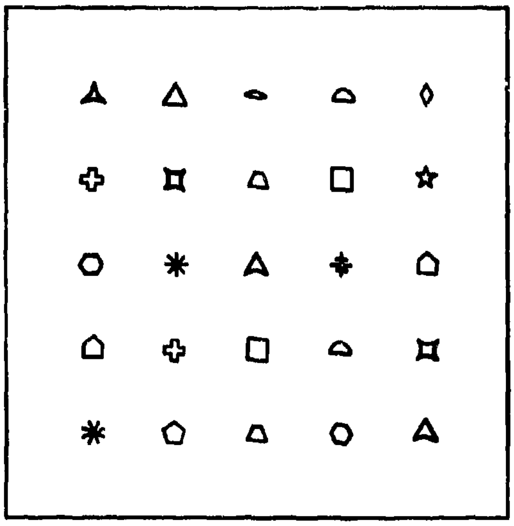

FIG. 10. Sketch of Symbol-Legibility Chart.

For the resolution and symbol-legibility tests, the three charts for each had patterns of different sizes. The gray-scale charts (Fig. 9) varied in that they had different contrast values. For each type of test, the observer was given a briefing card that showed each possible response and indicated how they were to be given.

Six observers were used in the tests, one Navy pilot and five technical civilian employees. All had uncorrected, binocular, near visual acuity of 20/17 or better as measured on the Armed Forces Vision Tester. Five of the six had previously participated as observers in a similar experiment.

PICTURE QUALITY CONTROL

To provide as nearly as possible the same display quality for each observer, brightness measurements were made on the monitor before and after each day's trials. Before the experiment began, the monitor was adjusted to what subjectively appeared to be a good picture of the RETMA resolution chart. A nine-step gray-scale chart (Fig. 3) was then viewed by the camera and displayed on the monitor. The brightness of each gray level was measured with a Spectra Brightness Spot Meter, Model UB $\frac{1}{4}°$, looking through a small opening in the tarp covering the cockpit. An attempt was made to keep this brightness profile constant throughout the tests. If the readings did not approximate those that were to be maintained throughout the test, brightness and contrast adjustments were

made. The values measured before the data-collection runs are shown in Appendix B. The observers were not allowed to touch the controls on the monitor.

PROCEDURE

After the observer was made acquainted with the cockpit controls (e.g., canopy, air conditioner), seat adjustments were made, and the tarp was put in place, instructions for the linear-grid resolution test were played over the intercom. The subject was to tell which way the lines were running in each pattern on the resolution test charts. The test was then conducted. When the test was completed, the gray-scale test instructions were given, and that test was run. The subject was instructed to tell which corner of each square on the gray-scale test chart was either darker or lighter than the other three. The first half of the program was then completed by conducting the symbol-legibility test. The subject was to identify each symbol on the chart by calling out the number corresponding to the symbol. The symbols and corresponding numbers were shown on a briefing card held by the subject. The viewing mode was then changed (tarp on to off or off to on), and the same tests were repeated in the same order, except with resolution and gray-scale patterns in different orientations, and symbols in different positions on each chart (a second set of charts was used). The observer was required to give one of the several possible answers for each pattern in all tests (forced choice), and he was instructed to give his "best guess" if he was not sure. The answers were recorded by the experimenter sitting outside the cockpit.

Two observers were tested daily, the first with the tarp over the cockpit, then off, and the second with the tarp off, and then on. This kept the open-cockpit test duration as short as possible to minimize the effect of the change in the sun's elevation angle. It also resulted in the two viewing conditions being tested in counter-balanced order.

RESULTS

Scores, in terms of percent correct for each observer for all tests, are shown in Appendix B. They indicate, as has been found in other such experiments, that there is a large variation in scores for a given condition among different observers (Ref. 1 and 2).

The mean scores for the three tests are shown in Fig. 11, 12, and 13 for the two viewing conditions.

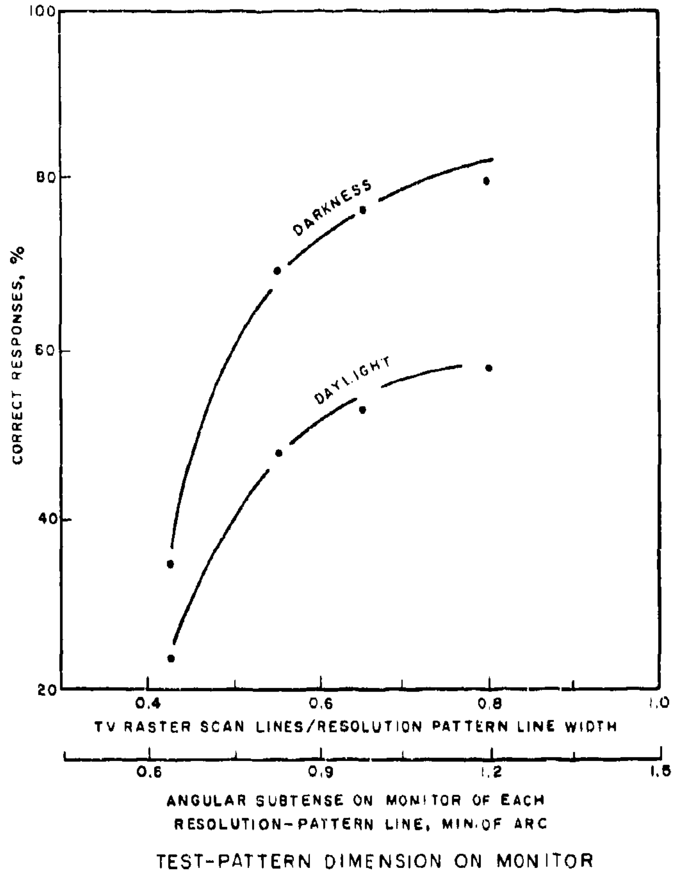

FIG. 11. Linear-Grid Resolution Test Results.

It is seen that observer performance under the daylight viewing condition is consistently worse than in darkness. In Fig. 11, the difference between dark and daylight performance is statistically significant ($p < 05$) for all but the smallest test pattern where both performances are near the chance level obtained from the forced-choice, 1-in-4 experimental design. The magnitude of the difference is indicated by comparing performance at the 50%-correct level. The object size as seen in daylight must be about 1.3 times as large as that seen in the dark environment simply to achieve the same performance.

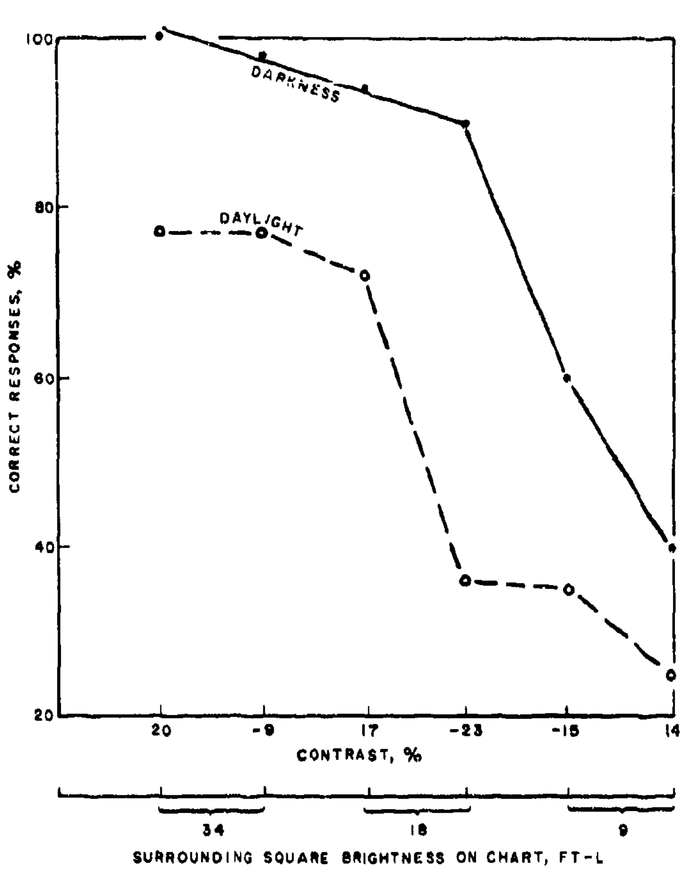

FIG. 12. Contrast Test Results. Chart performance is plotted in rank order of decreasing performance for darkness test.

The number of RETMA gray shades visible is also lower in the daylight environment. Performance is plotted in decreasing rank order in Fig. 12. It is seen that contrast between the disparate quadrant and the three adjacent quadrants is not the principal factor affecting performance. The overall brightness of the test squares is more important. Performance is higher on the charts whose surrounding squares in each pattern are brightest. As the brightness of the patterns decreases, performance drops. This may be partially due to operation of the TV camera with a fixed sensitivity setting. These results can also be seen in Ref. 1 and 2.

It is difficult to express the results of the contrast tests in terms of RETMA contrast materials since (1) the RETMA notation is usually used in a subjective-judgement context, and (2) RETMA steps are generally larger than those used in these tests. One comparison that can be made however, is for chart No. 2 which has a -23% contrast. The background brightness is equivalent to RETMA step No. 4 and the target is equivalent

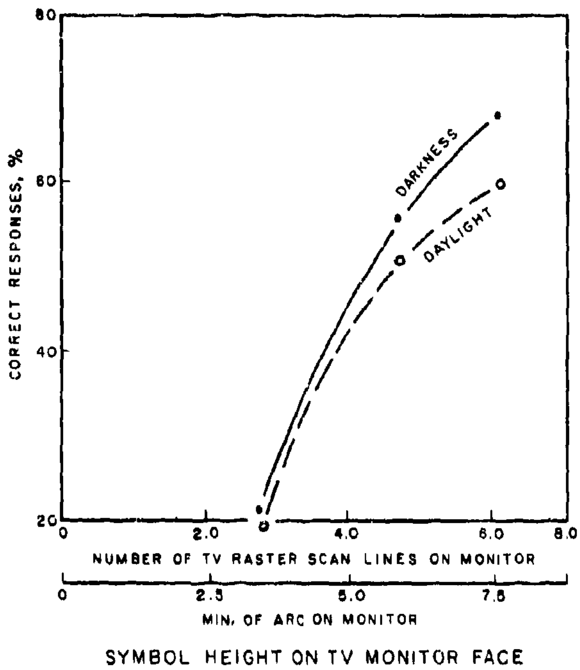

FIG. 13. Symbol-Legibility Performance.

to RETMA step No. 5. There were about 90% correct responses in the dark environment, so we may consider the system to have at least five gray levels. Performance on the same chart dropped to 60% correct in daylight. We may conclude that the addition of daylight to the viewing environment reduces the TV shades-of-gray by at least one RETMA gray level.

Although the mean scores for daylight symbol legibility are lower than those obtained under the darkness condition (Fig. 13), the differences are small and not statistically significant. It must be concluded from these tests that the addition of daylight to a high-contrast symbol-legibility task does not appreciably reduce the ability to discriminate the symbols.

The results of the resolution test can be compared in Fig. 14 to results from previous experiments in which the same general techniques were used. It is seen that these scores were higher than those from the 8-inch Conrac monitor in the dark (whose video input was from a 3-megahertz video recorder). They were lower than the 5-inch Hi-Brightness monitor that was tested in the daylight (tests described in Ref. 1 and 2, respectively). The data are shown only to demonstrate that the results all fall within the same general region. It is inappropriate to make system comparisons from these data.

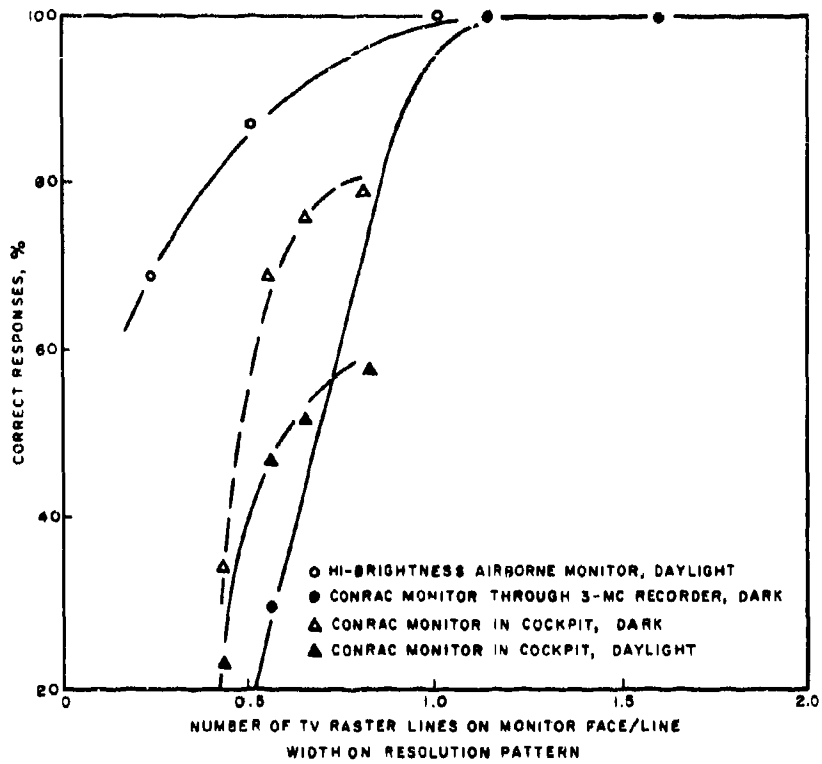

FIG. 14. Comparison of Resolution Test Results From Various NWC Experiments.

EXPERIMENT 3
EVALUATION OF A HIGH-RESOLUTION TV SYSTEM

INTRODUCTION

A data base has been established by three TV experiments conducted by this laboratory (Ref. 1 and 2, and Experiment 2). All tests were run with the same TV camera, and two of the three with the same monitor type. The measurements of resolution, gray-scale rendition, and symbol legibility are therefore characteristic of this one particular TV system. Validity of extrapolating the results to other systems was unknown.

The availability of a high-resolution, 875-line system provided the opportunity to test the generalization of our 525-line experimental results. The data would also provide the high-resolution system owners with a comparative evaluation of their system.

Testing was conducted in the laboratory under controlled experimental conditions. Observers were tested with gray-scale charts, Landolt C-ring (Fig. 15) and linear-grid resolution charts, and symbol-legibility charts on a TV monitor. The data obtained in these tests are graphically presented to allow direct comparison with results obtained on 525-line systems.

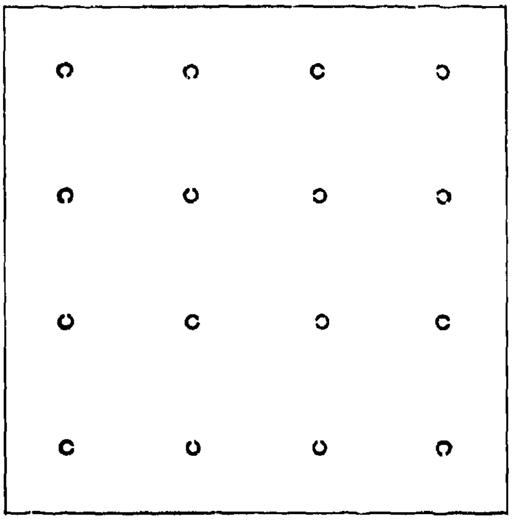

FIG. 15. Sketch of Landolt C-Ring Resolution Chart.

APPARATUS AND OBSERVERS

The experiment was conducted in a laboratory of the Naval Weapons Center at China Lake, California. Observers viewed presentations on a 17-inch, high-resolution TV monitor (Conrac Model CQF 17/C) at an effective viewing distance of 24 inches. The TV camera consisted of a two-unit Conrac camera head (Type TE-21-A) and a control unit (Type EBI-6171). The system had an 875-line rate, 2:1 positive interlace, and a bandwidth of 15 megahertz ±2 db. The camera was directly focused on the test charts via a Schneider-Kreuznach f1:2/50-mm lens. The experimental setup was similar to that shown in Fig. 1.

A series of four tests was administered to each observer. To familiarize the observers with content and procedure, briefing cards were furnished, and a practice chart and explanation were presented prior to each

type of test. The tests consisted of three Landolt C-ring resolution charts (Fig. 15), four linear-grid resolution charts (Fig. 8), three gray-scale charts (Fig. 9), and three symbol-legibility charts (Fig. 10). Levels of difficulty were achieved by maintaining a constant 14-foot distance between the TV camera and the test charts, and by varying the size of the test patterns on the charts. Differences on the gray-scale charts were made by varying target-to-background contrast.

Eight civilian technical employees were used in the experiment. All observers were required to have uncorrected, binocular, near visual acuity of 20/17 or better. Six of the eight observers had previously participated in similar tests.

PICTURE QUALITY CONTROL

A standard RETMA chart was initially used to obtain a "good-looking" gray-scale and resolution adjustment on the monitor. However, it was found that a higher level of monitor brightness was necessary to obtain reasonable performance on symbol legibility. A trade-off was made between gray scale and symbol legibility in choosing the final monitor setting for the tests. This resulted in poorer gray-scale rendition than possible, but acceptable symbol resolution. A Spectra Brightness Spot Meter (Model UB $\frac{1}{2}$°) was used to obtain brightness measurements on the gray-scale calibration chart (Fig. 3). Readings were first made directly on the illuminated gray-scale chart and then on the chart's image as presented on the face of the monitor. In an attempt to maintain, as nearly as possible, the same levels of brightness on the monitor face throughout the entire test series, brightness measurements were taken before and after each day's trials. When necessary, adjustments in brightness and contrast were made to approximate the original readings and thus maintain a fairly stable brightness profile throughout the tests. Observers were not allowed to make monitor adjustments. Records of the brightness measurements are given in Appendix C.

PROCEDURE

Each observer was brought into the laboratory and seated before the TV monitor. The experimenter adjusted the spacing goggles to the observer's sitting position. Before each test, the observer was shown the proper briefing card to acquaint him with the response procedure and test patterns. The instructions on responding to the grid resolution, gray-scale rendition, and symbol-legibility charts were the same as those given in Experiment 2. The subject was asked to indicate the location of the gap in each ring on the Landolt C-ring resolution charts. He was told he was being tested under the method of forced choice; namely, if he was not certain of a correct response, he was instructed to give his "best guess". Except for the symbol-legibility test, a practice chart was shown on the TV before the actual test began.

One experimenter recorded the observer's oral responses while a second experimenter manipulated the test charts. No response-time limits were set, and each observer was able to complete the test series within 25 minutes.

RESULTS AND DISCUSSION

Performance scores for each observer on each chart in the tests are shown in Appendix C. Mean scores are shown in Fig. 16 and 17. It is seen that performance on the resolution tests begins to degrade when the critical detail (gap size or line width) has less than one active TV scan

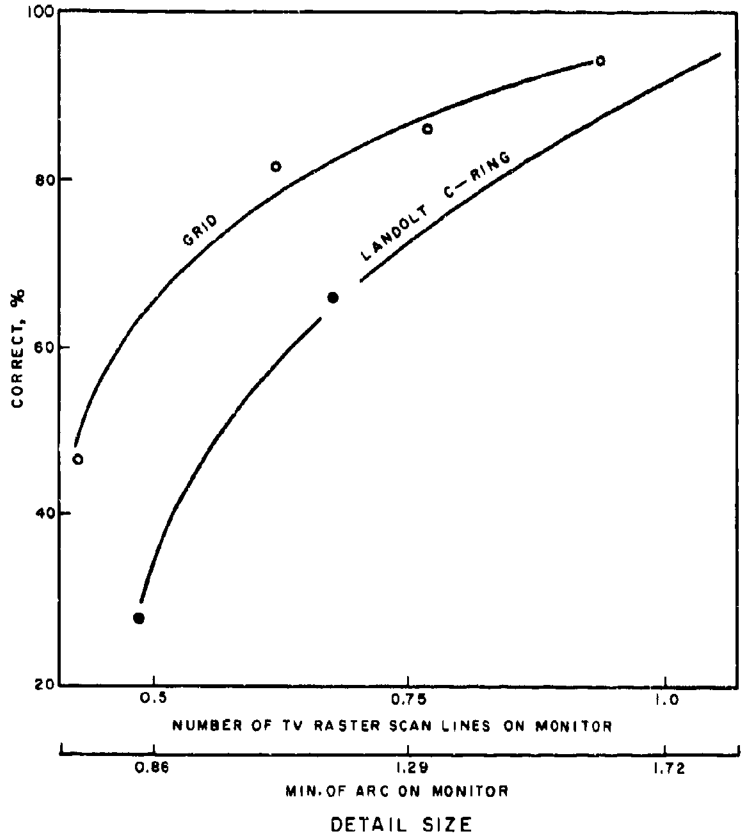

FIG. 16. Performance on Resolution Test. Results are plotted as a function of detail size: width of one line in the linear grid, and width of the gap in the Landolt C-ring. It is seen that an object on the chart covered by one TV scan line (and the blank space beside it) on the monitor face will subtend 1.72 minutes of arc to the subject.

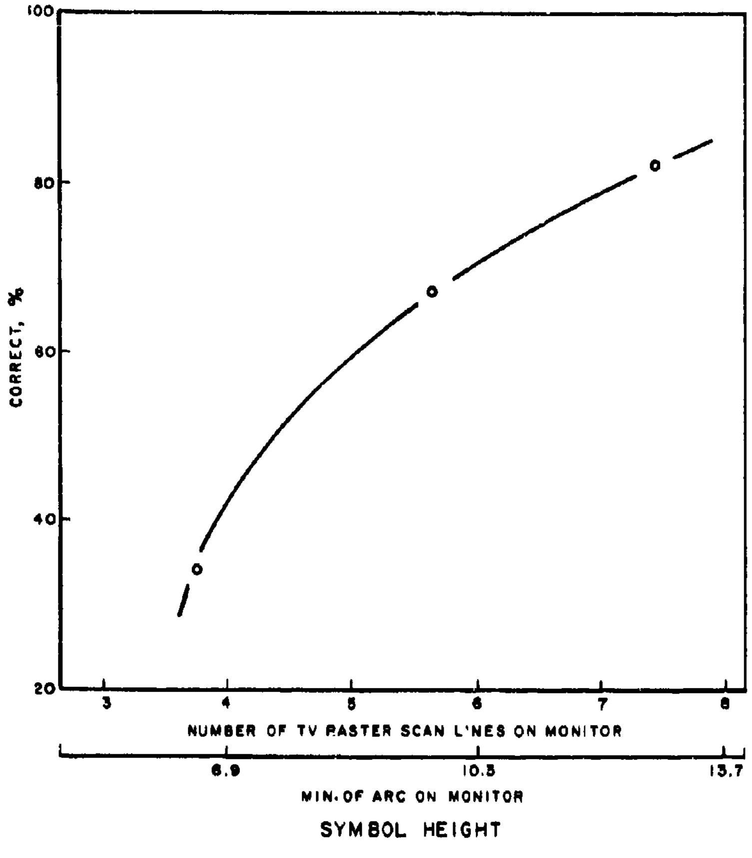

FIG. 17. Performance on Symbol-Legibility Test. Results are plotted as a function of symbol height on the monitor.

line crossing it. Symbol legibility also gets more difficult as the symbols decrease in size with only 40% correct responses when four active TV scan lines cross a symbol.

The symbol legibility data indicate that performance reaches the 90% correct level with 9 to 12 scan lines making up each symbol. The symbols subtend about 14 minutes of arc at 90% correct. A review of the literature has indicated that Elias, Snadowski, and Rizy (Ref. 3) obtained 90% correct performance with alphanumerics composed of four to five lines. In Ref. 4, the legibility of two different styles of alphanumeric symbols (Leroy and Courtney), was measured for 6, 8, 10, and 12 raster lines per symbol height. Legibility was not found to be significantly different for the two styles of alphanumerics. Results showed that 90% performance was reached at about eight scan lines per symbol height. The visual angle subtended by symbol height was related to resolutions of 6, 8, and 10

raster lines/alphanumeric in Ref. 5. Performance was 99% correct with 10 lines per symbol height and 13 minutes of arc symbol subtense.

A flying spot scanner was used to generate the number of TV raster lines making up alphanumerics on a TV monitor (Ref. 6). Identification performance was 90% correct with about 6.4 scan lines across the symbols and an angular subtense of 12 minutes of arc. The performance recorded in our experiment was worse than those cited above. Different symbols were used that evidently resulted in a more difficult identification task.

Results of the gray-scale test are shown in Fig. 18. As discovered earlier, performance was independent of contrast within the range

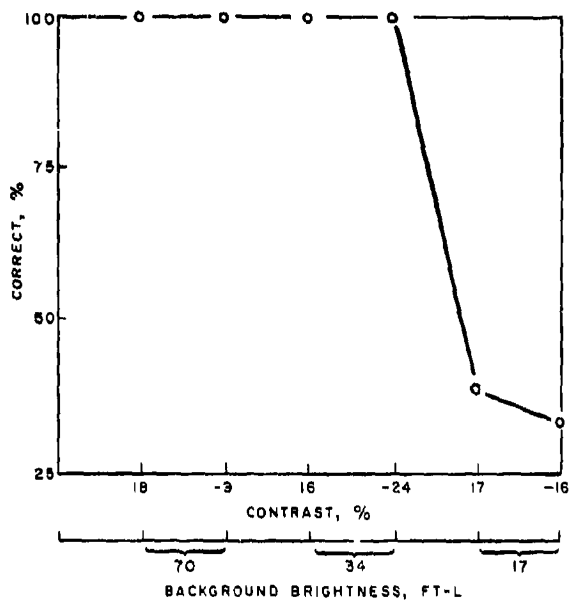

FIG. 18. Contrast-Rendition Test Results.

of values tested. The principal determining factor was the overall or background brightness level of the test patterns. Performance is poor on dark patterns. This was also found to be the case in Experiment 2. Many experimenters with TV have considered target/background contrast a principle variable, with little emphasis on brightness level. Our results suggest that the brightness of the scene being viewed by the camera, and perhaps the vidicon sensitivity, are more important than contrast as determinants of TV picture quality.

The results of the resolution and symbol-legibility tests are compared to previous NWC 525-line results in Fig. 19 through 22. The

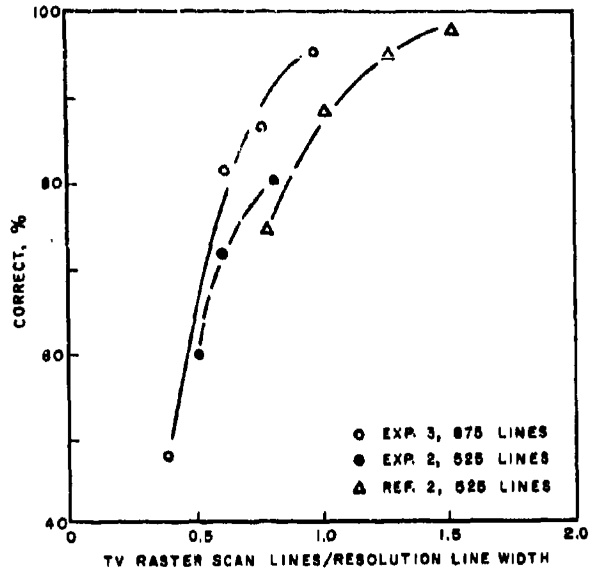

FIG. 19. Resolution Test Results From Previous Experiments.

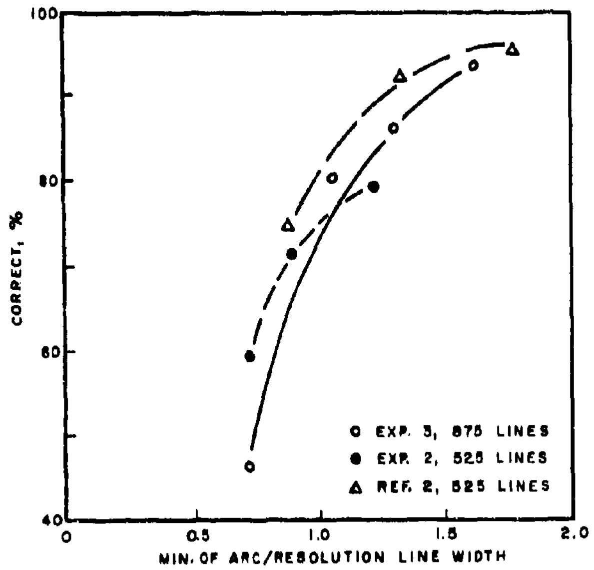

FIG. 20. Resolution Test Results From Previous Experiments (Data Replot).

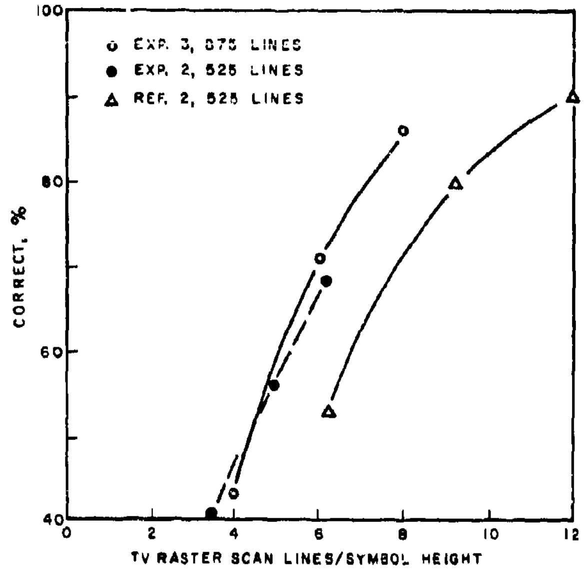

FIG. 21. Comparison of Symbol-Legibility Test Results With Those of Previous Experiments.

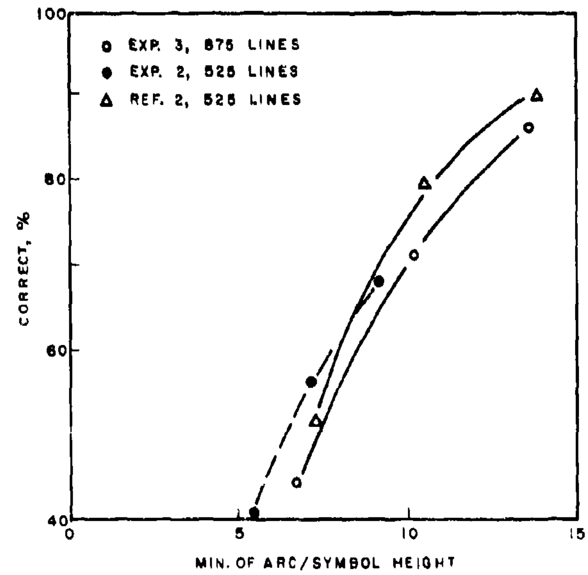

FIG. 22. Comparison of Symbol-Legibility Test Results With Results With Those of Previous Experiments (Data Replot).

poorer performance measured in Ref. 2 (Fig. 19 and 21) could be due either to the daylight viewing condition, or to the fact that a TV line subtended only 1.16 minutes as compared to 1.50 and 1.72 minutes in the other studies. That the latter is the case is indicated by a replot of the data (Fig. 20 and 22) as a function of angular subtense. There appears to be no real difference between study results.

This experiment has demonstrated that the 525-line data can be used as a basis for predicting performance on other TV systems. Performance must be expressed as a function of the number of TV raster lines making up the image, and the angular subtense of the image to the observer's eye.

Appendix A

BRIGHTNESS MEASUREMENTS AND TEST INSTRUCTIONS: EXPERIMENT 1

BRIGHTNESS MEASUREMENTS AND CONTRAST COMPUTATION

Brightness measurements given in Tables 3 through 5 were made with a Spectra Brightness Spot Meter with an eye-response filter.

TABLE 3. Brightness Measurements Made on Calibration Chart

Values are given in footlamberts. Means appear below the line in each sector.

Gray level	Reading, ft-l	Gray level	Reading, ft-l	Gray level	Reading, ft-l
1	1.0	2	4.5	3	9.5
	1.0		4.5		10.0
	1.5		4.5		10.0
	1.1		4.2		9.0
	1.4		4.3		9.2
	1.2		4.4		9.5
4	17.0	5	20.0	6	22.0
	16.5		19.5		22.0
	15.5		18.5		21.0
	16.5		19.0		22.3
	16.5		19.5		22.0
	16.4		19.3		21.9
7	29.0	8	33.0	9	36.0
	29.0		33.0		37.0
	28.0		33.0		36.0
	27.0		31.0		35.0
	28.5		33.0		36.0
	28.3		32.6		36.0

TABLE 4. TV Monitor Brightness Measurements Made During Test No. 1

Values are given in footlamberts. Means appear below the line in each sector.

Gray level	Reading, ft-l		Gray level	Reading, ft-l		Gray level	Reading, ft-l	
	Before run	After run		Before run	After run		Before run	After run
1	1.8	1.8	2	3.0	4.5	3	7.0	7.3
	2.0	2.2		3.5	4.2		7.0	7.5
	2.2	2.0		4.2	3.5		7.5	7.2
	2.4	2.0		4.3	3.7		8.5	7.2
	2.0	1.8		3.7	3.3		7.2	7.0
	2.1	2.0		3.7	3.8		7.4	7.2
4	20.0	21.0	5	25.0	27.0	6	28.0	28.5
	20.0	21.5		23.5	25.5		26.0	28.0
	21.5	21.0		25.5	26.0		28.0	27.5
	22.8	20.5		26.5	24.5		29.0	27.2
	20.5	20.5		24.5	24.0		27.2	27.0
	21.0	20.9		25.0	25.4		27.6	27.6
7	41.0	43.0	8	49.0	51.0	9	53.0	55.0
	41.0	42.0		49.0	50.0		52.5	53.0
	42.0	42.0		50.0	51.0		53.0	54.0
	42.5	42.0		50.0	49.0		53.0	53.0
	42.0	40.0		49.0	48.5		53.0	51.0
	41.7	41.8		49.4	49.9		52.9	53.2

TABLE 5. TV Monitor Brightness Measurements Made During Test No. 2

Values are given in footlamberts. Means appear below the line in each sector.

Gray level	Reading, ft-l		Gray level	Reading, ft-l		Gray level	Reading, ft-l	
	Before run	After run		Before run	After run		Before run	After run
1	3.0	2.5	2	3.5	3.5	3	7.2	7.0
	2.5	3.0		3.5	4.0		7.0	8.0
	2.5	2.5		4.8	4.5		9.1	8.7
	2.5	2.5		4.5	4.2		8.7	9.0
	2.5	2.2		4.2	4.5		9.0	8.5
	2.6	2.5		4.1	4.1		8.2	8.2
4	19.5	20.0	5	23.5	24.0	6	26.0	26.0
	20.0	20.0		24.0	23.5		26.0	26.0
	22.5	23.0		29.5	29.0		30.5	30.0
	23.0	22.5		29.5	29.5		30.0	31.0
	22.5	23.5		29.5	31.0		31.0	32.0
	21.5	21.8		27.2	27.4		28.7	29.0
7	41.0	41.0	8	51.0	50.0	9	54.0	54.0
	41.0	42.0		50.0	50.0		54.0	54.0
	41.0	42.0		52.0	54.0		54.0	55.0
	42.0	40.0		54.0	52.0		55.0	55.0
	40.0	43.0		52.0	56.0		55.0	58.0
	41.0	41.8		51.8	52.4		54.6	55.2

The contrast between the small square and its surroundings was computed from the equation

$$C = \frac{B_T - B_S}{B_S}$$

where B_T is the target brightness and B_S is the brightness of the surroundings (G4 paper).

VERBAL TRANSCRIPT OF TEST INSTRUCTIONS TO OBSERVERS

We are interested in collecting data on how well observers can count point-targets on a television monitor. Such data can be applied to the detection of aircraft groups, and identification of the number of aircraft in the group.

We are going to ask you to view the television monitor with your head up against the spacing goggles. This keeps the viewing distance the same for everyone. Please adjust your chair now so that you can sit up comfortably at the table with your head against the goggles.

The display that you're looking at is a large rectangle divided into squares by the black lines. Each square is a target area and may contain zero, one, two, or three targets. We would like you to start with the upper left-hand square and go across to the right, telling us how many targets you see in each square. When you're finished with the top row, start on the left in the bottom row and do the same. You must give an answer for each square. The choice of possible answers is zero, one, two, or three. You will notice that the targets vary in size and contrast. Some are lighter than their background, and some are darker. Some are fairly large, and others are smaller.

Now, for practice, give the answers for the chart you're looking at now.

Good, we're going to show you two more practice charts and then the 11 charts in the actual test. Here is the next practice chart. Go ahead and give us the answers for it.

And here is the last practice chart.

Now before we start the actual test, we would like you to put on these earmuffs. Once in a while we get some high-frequency noise from the TV monitor, and these will help filter it out. Go through the entire test with the earmuffs on, calling out the answers for each square. We'll write them down on a score sheet.

Appendix B

BRIGHTNESS MEASUREMENTS AND PERFORMANCE SCORES: EXPERIMENT 2

CONTRAST-CHART BRIGHTNESS

The contrast-rendition charts were made to cover a range of brightnesses from light (34 footlamberts) to dark (9 footlamberts). Brightness readings, taken directly on the charts, are shown in Table 6.

TABLE 6. Contrast-Chart Brightness Measurement, Experiment 2

Values are given in footlamberts. Means appear below the bottom line.

Chart 1			Chart 2			Chart 3		
Surrounding squares	Target square		Surrounding squares	Target square		Surrounding squares	Target square	
34.0	41.0		17.9	13.8		9.0	9.5	
34.0		31.0	18.0		21.1	9.0		7.5
34.5	41.5		18.0	13.9		9.3	10.9	
34.5		31.0	18.5		27.5	9.0		7.6
34.0	40.5		18.1	14.1		9.1	10.5	
34.5		31.5	18.2		21.5	9.1		8.0
35.0	42.5		18.5	14.7		9.2	11.0	
36.0		32.0	19.0		22.5	9.6		8.2
34.6	41.4	31.4	18.4	14.1	21.6	9.2	10.5	7.8

The contrast between the target square and the other three squares can be computed by the equation

$$C = \frac{B_T - B_S}{B_S}$$

where B_T is the target brightness, and B_S is the brightness of the other squares.

MONITOR BRIGHTNESS

The brightness measurements made on the monitor in the cockpit using the gray-level chart are shown in Table 7. The values in Table 7 are shown in Fig. 23 plotted against the actual chart brightness. This illustrates the contrast rendition of the system.

TABLE 7. Brightness Measurements Made on TV Monitor

Values are given in footlamberts.

Observer	Nine gray levels								
	1	2	3	4	5	6	7	8	9
1	8.5	9.0	12	22	25	28	43	49	54
2	7.0	10.0	16	30	34	40	52	55	57
3	11.0	11.5	15	26	28	30	46	52	57
4	9.5	10.0	14	24	26	29	44	50	56
5	12.5	13.5	18	27	30	33	47	52	58
6	16.0	17.0	21	28	30	33	46	50	55
TV mean	10.8	12.0	16	26	29	32	46	51	56
Chart	2.5	7.0	15	24	28	33	44	51	57

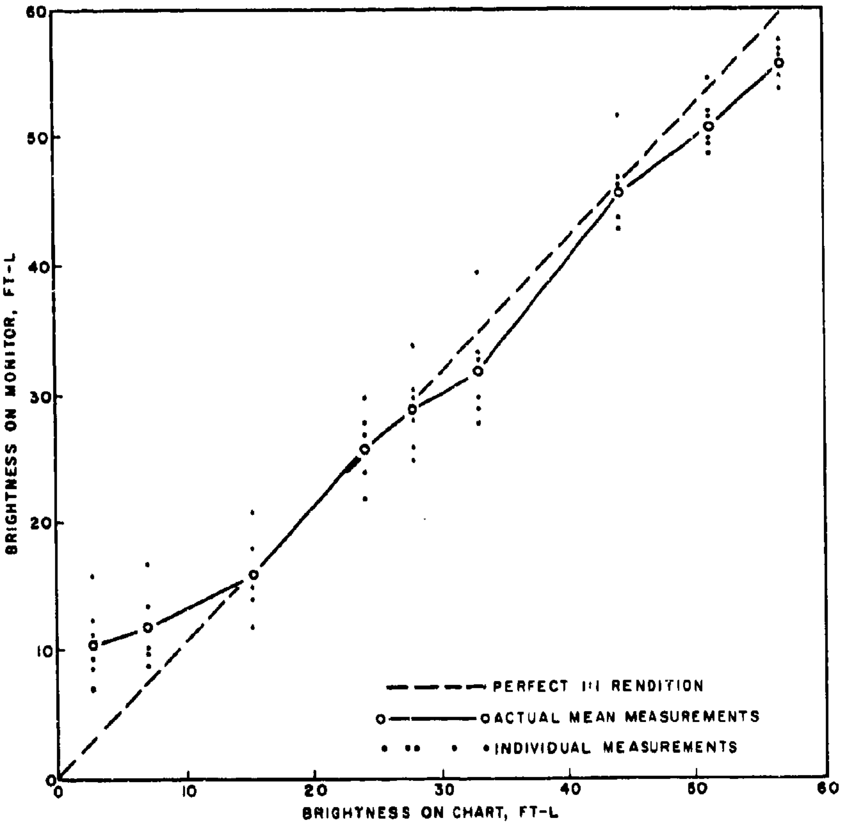

FIG. 23. Contrast Rendition of the TV System (Experiment 2).

PERFORMANCE SCORES

Performance scores are shown for each observer in all tests in Tables 8 through 10.

TABLE 8. Performance on Resolution Test

Scores given are number of wrong responses in 16 trials.

Experimental conditions	Chart number	Observer					
		1	2	3	4	5	6
Tarp on (dark)	1	1	3	3	4	6	2
	2	4	2	4	5	5	2
	3	2	5	6	5	6	5
	4	9	11	12	10	12	8
Tarp off (light)	1	4	11	6	5	9	5
	2	4	8	7	9	12	5
	3	7	11	12	5	9	6
	4	12	16	10	11	11	13

TABLE 9. Performance on Symbol-Legibility Test

Scores given are number of wrong responses in 25 trials.

Experimental conditions	Chart number	Observer					
		1	2	3	4	5	6
Tarp on (dark)	1	13	2	13	9	9	5
	2	10	5	20	15	11	6
	3	16	20	23	19	19	19
Tarp off (light)	1	8	9	18	10	7	8
	2	11	9	22	13	11	7
	3	16	19	23	20	22	18

TABLE 10. Performance on Contrast-Rendition Test

Scores given are number of correct responses in eight trials.

Experimental conditions	Chart number	Contrast, %	Observer					
			1	2	3	4	5	6
Tarp on (dark)	1	-9	8	8	7	8	8	8
		+20	8	8	8	8	8	8
	2	-22	5	8	8	8	8	8
		+17	6	8	8	8	5	8
	3	-15	1	2	8	7	3	0
		+14	3	1	8	7	6	4
Tarp off (light)	1	-9	7	8	8	0	7	7
		+20	6	5	8	4	7	7
	2	-22	2	2	8	6	8	8
		+17	1	1	8	4	2	2
	3	-15	4	1	3	2	1	1
		+14	4	4	3	0	3	3

Appendix C

BRIGHTNESS MEASUREMENTS AND PERFORMANCE SCORES: EXPERIMENT 3

CONTRAST-CHART BRIGHTNESS

Brightness readings of the target and surrounding squares were taken directly off the contrast-rendition charts and are presented in Table 11.

TABLE 11. Contrast-Chart Brightness Measurement, Experiment 3

Values are given in footlamberts. Means appear below the bottom line.

Chart 1			Chart 2			Chart 3		
Surrounding squares	Target square		Surrounding squares	Target square		Surrounding squares	Target square	
32.0	24.5		66.0	79.0		16.0	19.0	
33.0		39.0	67.5		61.5	16.5		13.5
34.0	25.0		68.5	82.0		16.8	19.5	
34.0		39.5	69.5		61.5	16.5		13.8
33.0	26.0		69.0	82.0		17.0	19.5	
34.0		41.0	71.0		64.0	17.0		14.3
34.5	27.0		73.0	86.5		17.3	20.8	
35.0		41.5	74.0		66.0	18.0		15.0
33.1	25.5		69.8	82.2		16.8	19.6	
		40.2			63.2			14.1

Target-to-background contrasts were computed by the equation

$$C = \frac{B_T - B_S}{B_S},$$

where B_T is the target brightness, and B_S represents background brightness.

MONITOR BRIGHTNESS

Brightness readings taken from the gray-level chart are presented in Table 12. To illustrate the TV system's contrast rendition, the

brightness readings from Table 12 were graphically represented against the direct brightness readings from the contrast chart in Fig. 24.

TABLE 12. TV-Monitor Brightness Readings Taken Before and After Each Day's Tests

Values are given in footlamberts.

Observer	Nine gray levels								
	1	2	3	4	5	6	7	8	9
1	2.0	2.2	4.0	11.0	15.0	21.0	44.0	55.0	57.0
2	2.0	2.0	2.5	11.0	15.0	23.0	44.0	55.5	58.0
3	1.5	1.2	1.5	7.0	12.5	20.0	40.0	51.0	56.0
4	1.5	1.5	1.5	8.0	12.5	21.5	42.0	56.0	59.5
5	2.6	2.5	3.0	10.0	16.0	21.5	36.0	48.0	55.0
6	1.7	1.5	2.2	9.7	15.0	20.5	38.0	52.0	56.0
7	1.5	1.5	2.5	10.5	17.0	25.0	43.0	52.0	56.0
8	1.0	1.0	2.0	8.0	13.5	20.5	33.0	45.0	53.0
TV mean	1.7	1.7	2.4	9.4	14.6	21.6	40.0	51.8	56.3
Chart	3.8	13.5	29.5	50.5	60.5	70.5	96.0	115.0	130.0

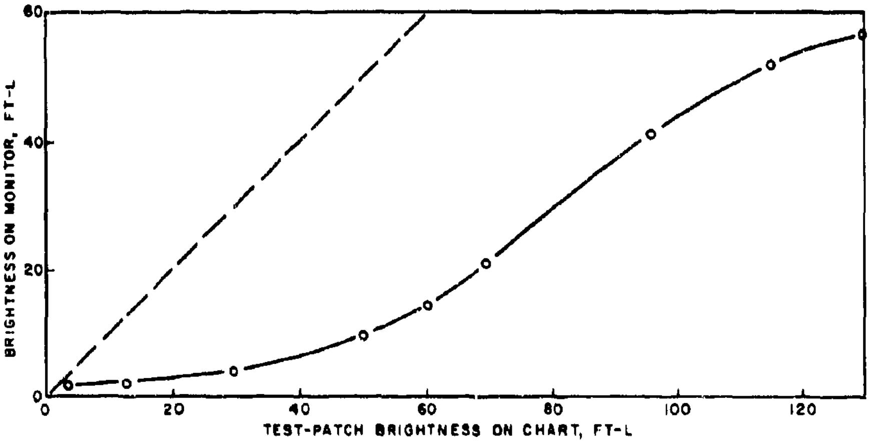

FIG. 24. Contrast Rendition of the High-Resolution TV System.

PERFORMANCE SCORES

Complete performance scores are given for all observers in Table 13.

TABLE 13. Performance Scores on All Charts in Experiment 3

Scores given are number of correct responses out of a possible 16.

Observer	Landolt C-rings			Linear grids				Contrast charts			Symbol charts[a]		
	1	2	3	1	2	3	4	1	2	3	1	2	3
1	16	11	6	14	14	13	6	16	16	5	18	12	7
2	15	15	6	14	14	14	6	16	16	5	19	16	9
3	15	16	2	15	15	15	11	16	16	4	20	20	14
4	16	10	4	16	12	15	8	16	16	4	20	15	4
5	15	10	6	16	13	12	9	16	16	3	22	18	12
6	15	7	4	16	16	13	9	16	16	8	18	15	7
7	16	10	7	15	16	13	6	16	16	3	25	25	13
8	16	6	3	16	10	11	6	16	16	11	20	14	8
Totals	124	85	83	122	110	106	61	128	128	43	164	135	74
Mean	15.5	10.6	4.7	15.2	13.7	13.2	7.6	16.0	16.0	5.4	20.5	16.9	9.2

[a] 25 correct responses possible.

REFERENCES

1. U. S. Naval Ordnance Test Station. Target Acquisition on Television: Preliminary Experiments, by Ronald A. Erickson and Ray E. Main. China Lake, Calif., NOTS, August 1966. (NOTS TP 4077).

2. ———. Airborne Television Monitor Evaluation, by Ronald A. Erickson, and others. China Lake, Calif., NOTS, January 1967. (NOTS TP 4209).

3. Elias, M. F., A. M. Snadowski, and E. F. Rizy. "Identification of Televised Symbols as a Function of Symbol Resolution," PERCEPTUAL AND MOTOR SKILLS, Vol. 21 (1965), pp. 91–99.

4. Mitre Corporation. Studies of Display Symbol Legibility. Part VI. Leroy and Courtney Symbols, by D. Shurtleff and others. Bedford, Mass., Mitre Corp., May 1966. (ESD-TR-65-136).

5. ———. Studies of Display Symbol Legibility. Part IX. The Effects of Resolution, Size and Viewing Angle of Legibility, by D. Shurtleff and others. Bedford, Mass., Mitre Corp., May 1966. (ESD-TR-65-411).

6. Baker, C. A., and R. M. Nicholson. "Raster Scan Parameters and Target Identification," in Proceedings of the Nineteenth Annual National Aerospace Electronics Conference. Dayton, Ohio, NAECON, May 1967. Pp. 285–290.

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13. ABSTRACT

Three experiments on target detection and identification with television (TV) were conducted in a laboratory setting. Experiment 1 found that small, square targets with a contrast of 18% against a darker background needed to subtend about four TV raster scan lines on the TV monitor to be detected. Extrapolation of the data indicates that targets with 7% contrast against a lighter background require about six TV lines across them to ensure detection.

Experiment 2 compared observer performance on several TV monitor viewing tasks in a daylight environment to performance in a darkened environment. Performance on the shades-of-gray test and the resolution test was worse under daylight conditions. One less shade-of-gray (by the RETMA standard) was discernible in daylight than in darkness. The critical detail in the resolution patterns had to be 1.3 times larger in daylight than in darkness to obtain the same performance level. There was no significant difference between symbol legibilities under the two conditions.

Experiment 3 was conducted with an 875-line TV system. Measures of resolution and symbol legibility compared favorably with previous 525-line data when results were expressed either as a function of angular subtense of a target to the observer or the number of scan lines on the monitor crossing the target. The results are compared to other studies of symbol legibility.

It is concluded that the 525-line data can be used to predict performance on other TV systems if performance is expressed as a function of the number of raster scan lines making up the image and the angular subtense of the image to the observer's eye.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Target Detection on Television						
Target Identification on Television						
Television						
Lighting Effects on Television						
Aircraft Television						

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